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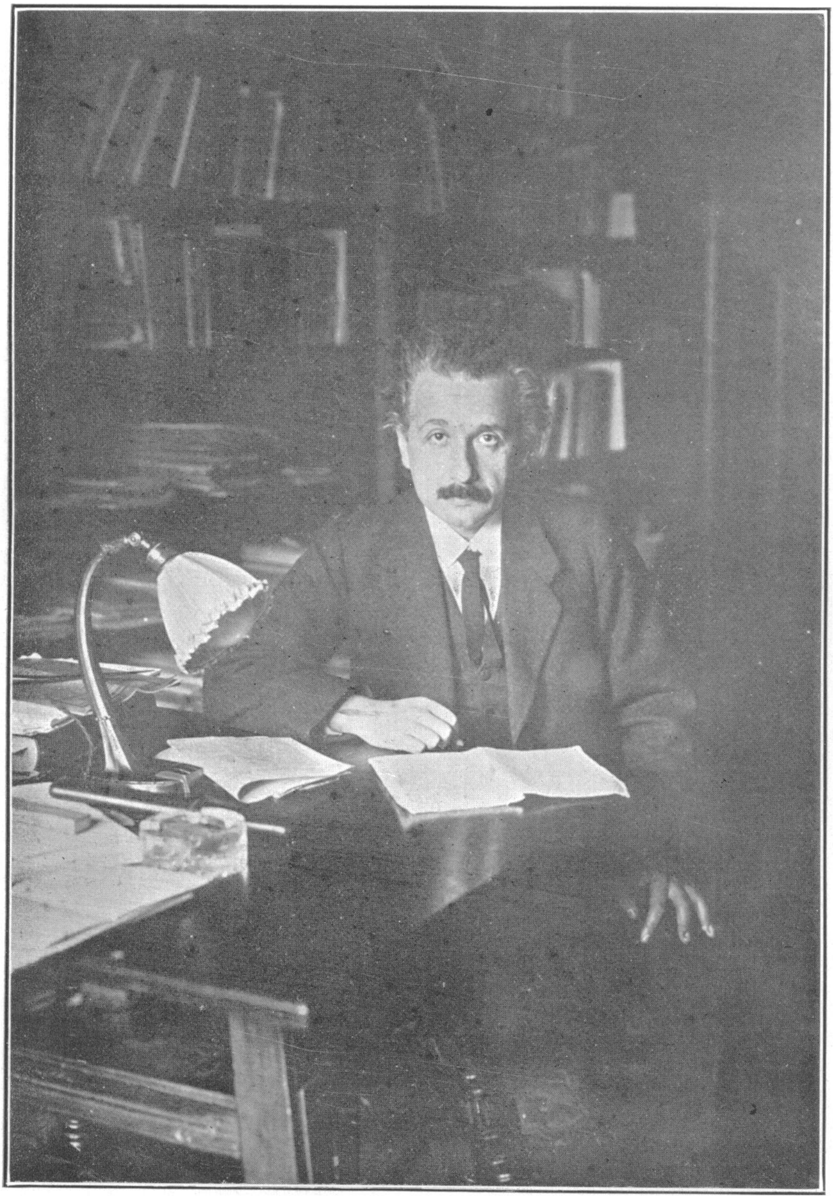


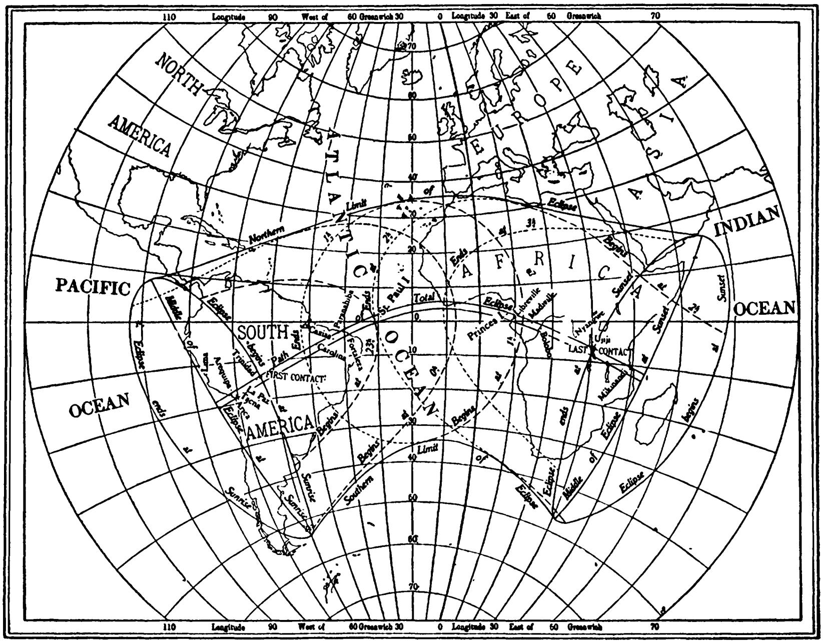
Professor Albert Einstein,
University of Berlin.

THE PROGRESS OF SCIENCE

THE SOLAR ECLIPSE OF MAY 29, 1919, AND THE EINSTEIN EFFECT

THE supposed verification, by British astronomers during the solar eclipse of May 29, 1919, of the Einstein prediction that rays of light, while passing near the sun, would be bent out of their straight course by the sun's gravitational pull, like any flying projectile, has made, says Dr. L. O. Bauer,[1] an eclipse of the sun of more than passing interest, not alone to the astronomer, but also to the geophysicist, the mathematician, the physicist, and, in fact, to the philosopher, in general.

If a star-ray, on its way to the earth, just grazed the sun's limb, then the star, as seen by a terrestrial observer, or caught on a photographic plate, would either not be displaced at all, or it would be displaced by a certain minute amount, a. If the principles of the Newtonian mechanics hold for particles moving with the velocity of light (186,000 miles a second), then on the basis of Maxwell's electromagnetic theory of light, the apparent displacement, a, away from the sun would amount to $0''.87$; this was the shift predicted by Einstein in his first theory of relativity. According to his later or generalized theory of relativity, which brings under the same purview electromagnetic and gravitational phenomena, the star would be displaced apparently by the amount $2a$ or $1''.74$. If the ray of light passed through the sun's gravitational field at the distance from the



THE PATH OF THE TOTAL SOLAR ECLIPSE OF MAY 28–29, 1919.

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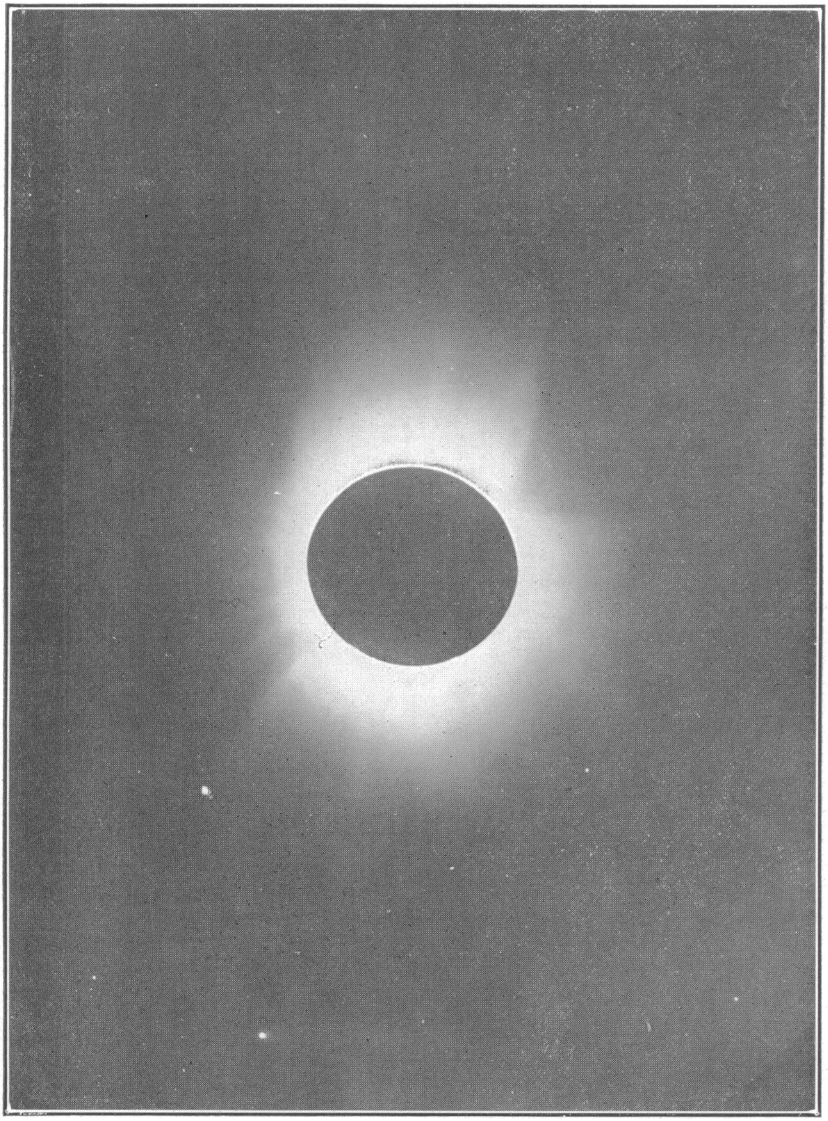
[1] See résumé of public lectures given by him before various societies and universities, published in the issue of *Science* for March 26.



THE SOLAR CORONA DURING THE ECLIPSE OF MAY 29, 1919, as photographed by Dr. C. G. Abbot, of the Smithsonian Institution, at an elevation of 14,000 feet, near La Paz, Bolivia.

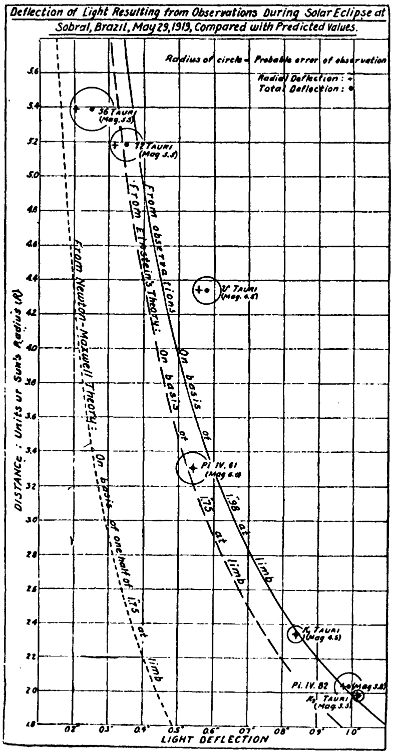
center of the sun twice its radius, as was about the case for the nearest star concerned in the British observations, the apparent displacement would simply be one half of the amounts just stated. In brief, the deflection would vary inversely as the distance.

Now, according to the results from the best of the photographic plates obtained by the two British expeditions, one to Sobral, Brazil, and the other to the Île of Principe, west coast of Africa, the displacements of the stars accorded best with the predictions based on Einstein's later theory. The British astronomers were exceedingly fortunate in having the opportunity of making the tests during an eclipse when there was a rich field of bright stars, the Hyades, sufficiently close to the sun, so that the quantities to be measured were well within the observational errors.

Professor W. W. Campbell's expedition made a test during the solar eclipse of June 8, 1918, at Goldendale, Washington, but, unfortunately, his observations had to be made on ninth magnitude stars, distant from the sun, two times or more the farthest star used by the British. His party was therefore obliged to work with much more minute quantities. The result from all of the observations was a mean displacement of 0″.05 in the right direction; but agreeing better with the predicted value (0″.08) on the basis of the Newtonian principles, than with that (0″.15) computed according to Einstein's later theory.

The combined result of the British and American tests would accordingly be that *light has weight*, besides exerting a measurable pressure; just how much weight depends upon whether the Newtonian or the Einstein principles are ultimately found correct. Astronomers are stimulated to make further tests in view of the important astronomical consequences of the Einstein theory; preparations by British astronomers are already under way for observations during the solar eclipse of September, 1922, which will occur in Australia, though the stellar conditions will not be as favorable as they were last year.

The importance of the subject has naturally caused some to advance possible other causes for the observed light deflections. Thus such an eminent solar physicist as Dr. H. F. Newall, of the Cambridge Observatory, while he is disposed to admit a possible effect according to Newtonian mechanics, prefers considering that the balance of the observed deflection of light is attributable to refraction in the solar atmosphere as mapped out, for example, to a certain extent by the solar corona.



THE CHART, CONSTRUCTED BY THE DEPARTMENT OF TERRESTRIAL MAGNETISM, OF THE CARNEGIE INSTITUTION, gives a graphical representation of the law of variation with distance followed by the observed deflections for each star. Excepting the most distant star (56 Tauri), each star shows a deflection agreeing better with the Einstein value than with the Newton-Maxwell one. The probable error of observation is shown by the size of the circle around each star.

It would also appear, according to Dr. Bauer's investigations, that the observed deflections are not strictly radial, *i.e.*, not wholly in the direction of the sun's radius, indicating that there are some effects superposed upon the simple Newton, or Einstein, effects. He finds that the non-radial effects occur in a systematic manner and not accidentally as they would if they were purely observational errors. He also finds that for the same distance a star in the polar regions of the sun showed a somewhat larger displacement than one in the equatorial regions. The question is raised, among others, how completely it was possible in the British observations to eliminate differential refraction effects as the rays passed through the earth's atmosphere.

Dr. Bauer's expedition was one of several expeditions sent out by the Department of Terrestrial Magnetism of the Carnegie Institution of Washington to make geophysical observations, the data from which are proving of interest in the discussion of the possible disturbing effects on the observed deflections of light. He himself observed the memorable eclipse at Cape Palmas, Liberia, where totality lasted longer, 6 minutes and 33 seconds, than at any other accessible station. He characterizes this eclipse as the most magnificent one of the four he has thus far observed; not only was the corona beautifully and finely developed but also a striking crimson prominence appeared on the sun's southeast limb which shot up 100,000 miles and had a base of 300,000 miles.

Dr. Bauer concludes with reference to the observed light deflections that "the best attitude to take is that of open-mindedness and to let no opportunity pass by for further experimental tests," and that "one of the most satisfactory results has been the stimulus imparted to further research in many fields which is bound to bear fruit."

PROFESSOR EINSTEIN ON THE THEORY OF RELATIVITY

IN an article contributed to the London *Times*, Professor Albert Einstein has undertaken to present his theory of relativity in a form comprehensible to readers not trained to think in mathematical formulas. He calls attention to the fact that the ancient Greeks knew that the motion of a body must be described in reference to another body. In physics the bodies to which motions are spatially referred are termed systems of coordinates. The laws of mechanics of Galileo and Newton can be formulated only by using a system of coordinates.

The special relativity theory is the application of the following proposition to any natural process: "Every law of nature which holds good with respect to a coordinate system *K* must also hold good for any other system *K'* provided that *K* and *K'* are in uniform movement of translation." According to the Maxwell-Lorentz theory of electro-dynamics, however, light in a vacuum has a definite and constant velocity, independent of the velocity of its source.

These two principles have received experimental confirmation, but do not seem to be logically compatible. The special relativity theory achieved their logical reconciliation by making a change in kinematics, that is to say, in the doctrine of the physical laws of space and time. It became evident that a statement of the coincidence of two events could have a meaning only in connection with a system of coordinates, that the mass of bodies and the rate of movement of clocks must depend on their state of motion with regard to the coordinates.

But the older physics, including the laws of motion of Galileo and Newton, clashed with the relativistic kinematics. Physics had to be modified. The most notable change was a new law of motion for very rapidly moving mass-points, and this soon came to be verified in the case of electrically-laden particles. The most important result of the special relativity system concerned the inert